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DEPARTMENT OF COMMERCE

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BY

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STATE REGULATIONS GOVERNING THE USE OF TROLLEY WIRES IN MINES[1]

By L. C. Ilsley[2] and R. A. Kearns[3]

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THE HAZARD OF TROLLEY WIRES

State safety codes give more attention to the question of trolley-wire installation than to any other phase of mine regulations pertaining to the use of electrical equipment. This attitude on the part of legislators is to be expected because trolley circuits offer a greater hazard than other circuits common to electrical installations in mines. In fact, this danger is so great that in mines outside of the United States the requirements either prohibit or greatly curtail the use of trolley circuits.

The three major hazards presented by a trolley circuit are (1) shock to persons, (2) the igniting of mine explosions, and (3) the igniting of mine fires. Most of the regulations are intended to lessen the first danger.

Shock Hazard

Of all circuits in mines, trolley circuits offer the greatest shock hazard. Most other circuits can be provided with a certain amount of insulation which prevents a person from coming in contact with the bare wire, but trolley circuits must be bare for their entire length. Most other circuits can be installed in such a manner as to prevent contact with them, but trolley wires must follow the alignment of the track, and usually because of the lack of head room they are so low that they offer a special hazard. In following the track, trolley circuits must pass under good and bad roof and encounter wet or dry conditions, as the case may be.

Some of the adverse conditions just mentioned can be modified, but generally at a considerable expense to the operator. Narrow roads can be widened to give clearance along the roadway on the side opposite trolley circuits. Bad roof can be taken down and additional supports placed, and where the roof is very bad, an arched support can be used. Top or bottom rock can be removed to make greater height. Drainage conditions can be improved. All of these changes which

1 - The Bureau of Mines will welcome reprinting of this paper, provided that the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Circular 6220."

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make for a good safe trolley installation add to the cost of mining and could be carried to a point that would make this cost prohibitive.

A high proportion of the total shock accidents caused by electricity in mines comes from contact with trolley circuits. In some States the percentage of fatal accidents caused by contact with trolley wires is high, and in all States it is greater than necessary were proper precautions observed.

Gas and Dust Ignition Hazard

The hazard most to be feared from trolley wires is in connection with the initiation of major disasters. The arc from a 250 or 500 volt trolley wheel is most certain to set off gas if an explosive mixture is present at the point where such arcing takes place. The trolley wire with its feeder circuits frequently causes fires and offers a real gas and dust ignition hazard.

Track return is one of the greatest objections to the trolley circuit because it almost always uses a ground. This return often presents a hidden and unexpected danger due to the wandering of the return current in finding the best path back to the generators. Improper bonding of the track or no bonding may force the return current beyond the limits of the trolley-wire installation, even to the face workings where arcing at unbonded joints offers a serious hazard to the safety of all in the mine. Such cases have been called to the bureau's attention.

Fire Hazard

Many disastrous mine fires have been attributed to trolley circuits. This applies to metal mines particularly, although such fires have taken place in coal mines.

STATE REGULATIONS

Table 1 shows that a number of different States have tried to help the situation by the enactment of regulations governing the use of trolley circuits:

Discussion of Regulations

Item 1: Trolley wires to be shown on plan map.-- Seven States insist on this. There are two vital safety reasons for this requirement. First, the management shall at all times be informed how near the working areas the trolley circuits are being installed and shall take the responsibility for the liability of gas ignition at the face workings of gassy mines. Second, when there is a disaster, those in charge of rescue work may know from the map the position of all electrical equipment, including line wiring.

Item 2: Hangers to be efficiently insulated.-- Eight States have this regulation. From the standpoint of safety the rule is needed to minimize the fire hazard; such a requirement is also desirable from the standpoint of operation.

Item 3: Hangers properly spaced to prevent sag.-- This rule is covered by the safety codes of 10 States. It is necessary for both safety and efficiency.

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Table[1] .- Rules relative to the use of trolley wire in mines.

States	Trolley wire to be shown on plan map	Hangers to be efficiently insulated	Hangers to be properly placed to prevent sag	Trolley wires to be suitably supported	Sag between supports "limited" to	Trolley to be installed on one side of roadway	Trolley wire to be shielded	Trolley to be maintained	Rule for termination of trolley wire	Forbidden to use trolley in working rooms	Power or lighting wires or both on same side as trolley wire	Trolley installed outside of rail	Operating locomotives in gassy section of mine prohibited	Lighting circuits fastened to drilled trolley ear	Voltage on trolley circuit limited	Means of cutting off power on branch circuits specified	Method of shielding or guarding suggested	Specific requirements for surface circuits	Stricter requirements for future installations	Height above rail or floor a safety factor	Size of trolley wire specified	Indirect ovation of trolley wire	Illumination requirements for shielded points	Trolley wire to be sectionalized
Alabama							Yes													Yes				
Arizona																			Yes	Yes				
California (all Mines)						Yes	Yes					Yes			Yes			Yes		Yes				
California(mines other than coal)	Yes	Yes		Yes	3 in	Yes	Yes				Yes	Yes			Yes		Yes	Yes	Yes	Yes		Yes	Yes	
Colorado (coal)	Yes						Yes										Yes					Yes		
Colorado (metal)			Yes		3 in	Yes	Yes					6 in			Yes	Yes				Yes				Yes
Idaho							Yes										Yes							
Illinois (coal)							Yes								Yes									
Illinois (metal)	Yes	Yes	Yes	Yes	3 in	Yes	Yes				Yes			Yes			Yes			Yes		Yes	Yes	
Indiana		Yes	Yes[2]	Yes		Yes	Yes	Yes				5 in				Yes	Yes							
Iowa																						Yes		
Kansas																								
Kentucky		Yes	Yes	Yes			Yes[3]				Yes								Yes	Yes				
Maryland				Yes			Yes																	
Michigan																						Yes		
New Jersey																			Yes	Yes				
New York (mines other than coal)	Yes	Yes	Yes	Yes	3 in		Yes										Yes		Yes			Yes	Yes	
Ohio		Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes	6 in			Yes				Yes					
Pennsylvania (bituminous)	Yes	Yes	Yes	Yes	3 in	Yes	Yes				Yes		Yes	Yes	Yes	Yes	Yes			Yes		Yes		
Texas			Yes	Yes		Yes	Yes	Yes				6 in							Yes	Yes				
Utah (coal)	Yes	Yes	Yes	Yes		Yes	Yes		Yes		Yes		Yes				Yes		Yes	Yes		Yes		
Utah (metal)	Yes	Yes	Yes	Yes	3 in	Yes	Yes				Yes						Yes		Yes	Yes		Yes	Yes	
Virginia							Yes								Yes		Yes			Yes				
Washington			Yes	Yes	3 in		Yes						Yes		Yes	Yes	Yes		Yes	Yes		Yes		
West Virginia							Yes				Yes		Yes				Yes			Yes				
Wyoming						Yes	Yes				Yes						Yes							

1.- At all places less than 6½ feet above rail.

2.- Wire to be kept taut.

3.- At landing or partings where trolley is less than 6½ feet above rail.

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A sagging line is dangerous to the motorman, as it is constantly arcing and difficult for the trolley wheel to follow. Good workmanship tends to better operation and increased production.

Item 4: Trolley wire to be suitably supported.--This item is included in 12 codes of 11 States. It is a sensible requirement which tends to safer and more satisfactory operation. The constant operation of the trolley wheel under considerable tension requires sturdy supports. Slack and fallen trolley lines are dangerous not only to the motorman but to all other men working near the lines.

Item 5: Sag between supports limited.--This regulation is included in seven State codes and is a specific requirement which, if followed, will insure that the lines are taut. A limit of 3 inches is specified in all cases.

Item 6: Trolley to be installed on one side of roadway.--Nine States and 11 codes include this requirement. This is an essential safety measure, especially where men must travel along haulage roads. Ohio is still more specific in keeping the trolley wire on the side opposite room necks and refuge holes.

Item 7: Trolley wire to be shielded.--This ruling is strictly a safety requirement, and is covered in 21 codes representing the regulations of 18 States. There has been a general agreement, and rightly so, that when trolley wires are less than 6-1/2 feet from the rail, they should be shielded to prevent accidental contact with persons passing under or alongside them, especially at points where men have to expose themselves to this hazard. Undoubtedly many fatal accidents from trolley circuits might have been avoided had this regulation been strictly enforced.

Item 8: Trolley wire to be maintained.--This item, which would seem essential to good practice, has been generally overlooked and is covered by only two States. It is just as essential to maintain electrical equipment in good condition day by day as it is to have it properly installed in the beginning.

Item 9: Rule for termination of trolley wire.--This item is covered by Ohio, which forbids carrying trolley wire into any entry beyond the outside corner of the last breakthrough. Utah also covers this item in a rule requiring that trolley wire be kept back of the last breakthrough and at least 50 feet back of the first room where pillars are being drawn. Every State ought to have a rule governing the termination of trolley circuits in gassy mines.

Item 10: Forbidden to install trolley wire in working room.--Ohio covers this item in a rule which states that "No trolley wire shall be extended into or maintained in any room while being used as a working place."

Alabama perhaps covers this item, indirectly for gassy rooms, under the rule which states that "Trolley wires are prohibited in any part of the mine where safety lamps are used." The probable intent of this rule could undoubtedly be greatly improved by rewording. As the wording now stands, there might be a tendency to keep safety lamps out of mines where they are badly needed in order that trolley circuits might remain. Rooms should not be permanently wired.

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Item 11: Power or lighting wires or both on same side as trolley wire.--This safety requirement, intended to insure one side of the roadway for save travel as far as electric shock is concerned, is a part of nine different codes affecting the laws of eight States.

Item 12: Trolley installed outside of rail.--Five States have deemed it necessary to enact this ruling which tends to safeguard the motorman by removing the trolley to one side. The wire to one side tends to prevent low-hanging wire from coming in contact with loaded cars.

Item 13: Operating locomotive in gassy section of mine prohibited.--This item is included in the regulations of four States. The intent of this rule is to avoid possible gas ignition from the arcing trolley wire. It is another way of stating where the trolley circuit should be installed. If there is no trolley wire, then there can not possibly be an arc from the improper use of the trolley locomotive.

Item 14: Lighting circuits fastened by means of drilled trolley ear.--This rule, which is covered by two States, insures good installation practice and a certain measure of increased safety.

Item 15: Voltage on trolley circuit limited.--This is primarily a safety measure, and from the standpoint of shock hazard it is an important one. It is quite possible that were all States to start anew, no pressure in excess of 250 volts would be permitted for operation of trolley circuits. There seems to be a strong feeling that voltage above 250 adds too great a shock hazard, and several States have legislated against the use of higher voltage. Seven States mention the question of voltage in their safety codes.

Item 16: Means of cutting off power on branch circuits specified.--In the maintenance of circuits in mines, men should not be called upon to work on live conductors. This item, which is a part of the code of four States, permits the isolation of branch circuit when work is to be done on any part of it.

Item 17: Method of shielding or guarding suggested.--Not only have a number of States insisted that trolley circuits shall be guarded, but 12 States also give suggestions as to how this should be accomplished. This shows how dangerous trolley circuits are considered, when looked upon as a personal hazard.

Item 18: Specific requirements for surface circuits.--Most of the rules apply to trolley circuits installed underground. However, two States, California and Utah, have specific regulations for surface trolley circuits about mines, which if not well installed, may offer a real shock hazard.

Item 19: Stricter requirements for future installations.--The general feeling of uneasiness in regard to trolley circuits is reflected in the fact that nine States have made more strict regulations to govern new installations than those that already exist covering circuits already installed. There is undoubtedly room for further work along this line.

Item 20: Height above floor or rail a safety factor.--The fact that 13 States have rules governing the height of the trolley wire above the floor or rail

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again emphasizes the generally recognized danger of trolley wire as it exposes the workman to shock hazard in his daily routine work. It must be well above the height of the average man to remove this menace.

Item 21: Size of trolley wire specified.--In no Code is the size of trolley wire specified. From the standpoint of mechanical strength, wire below 2/0 should not be used. From the standpoint of operating voltage, 4/0 should probably be used in most 250-volt installations.

Item 22: Indirect mention of trolley wire.--This item was included to cover those cases where the trolley circuit was only incidentally mentioned; the rule has little if any bearing on the safe installation or maintenance of the trolley circuit itself.

Item 23: Illumination requirements for shielded points.--As a natural consequence of the rule for shielding wire at points where men have to work under or near the wire, the additional requirement is made that such points shall be adequately illuminated. This rule is included in codes of four States.

Item 24: Trolley wire to be sectionalized.--This is a requirement of Colorado's safety code and one that might well be in any safety code. Such sectionalization not only is a safety measure for men working on defective lines, but often will assist the operator in keeping a portion of his mine in operation while the damaged part is under repair. Lines should be sectionalized at least every 2,500 feet.

CONCLUSIONS

Twenty-six safety codes have been studied and about 175 rules have been considered in Table 1. In gathering together these data it is possible that other rules having application may have been overlooked. However, it is believed that most of the regulations dealing specifically with trolley circuits have been included.

In making a study of this kind one is impressed with the general recognition that is given to this hazard from the standpoints both of shock and ignition. As an advocate of safety, the U. S. Bureau of Mines can not encourage the use of trolley circuits in any mine if some other practical substitute can be used. In this connection the bureau wishes to call attention to the so-called "wireless mine" in which the operator endeavors to have no permanent wiring, using portable battery power for furnishing the electrical energy at the working face. This problem is covered fullin in Cooperative Bulletin 42 (C. W. Owings and D. C. Jones: Efficiency, Cost, and Safety of Storage-Battery Equipment in Bituminous Coal Mines, and some Comparisons with Wired Transmission of Power) of the U. S. Bureau of Mines and Carnegie Institute of Technology, published in 1929.

Composite Code for Trolley Circuits

The Pennsylvania Bituminous Mine Law, which includes one of the most comprehensive sets of regulations concerning trolley circuits, has been selected as a framework upon which to build a code containing the essential requirements of all the codes considered. The composite code follows:

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1. A plan shall be kept at the mine, showing the location of all stationary electrical apparatus in connection with the mine electrical system, including permanent cables, conductors, lights, switches, and trolley lines . . .

2. In underground roads the trolley wires shall be installed as far to one side of the passageway as is practicable, and securely supported upon hangers, efficiently insulated, and placed at such intervals that the sag between points of support shall not exceed 3 inches.

3. All other wires, except telephone, shot-firing, and signal wires, shall be on the same side of the road as the trolley wires.

4. At all landings and partings where men are required regularly to work or pass under trolley or other bare power wires which are placed less than 6½ feet above top rail, a suitable protection shall be provided. This protection may consist of channeling the roof, placing boards along the wire, so as to extend below it, or the use of other approved safety devices.

5. All branch trolley lines shall be fitted with an automatic trolley switch or section insulator and line switch, or with some other device that will allow the current to be shut off from such branch headings.

6. Where wires for electric incandescent lamps are connected to the trolley circuit, the trolley ear to which connection is made shall be drilled to receive the lighting wires and provided with a set screw for securing the wires in place. Lighting wires shall not be wrapped or tied about the stems or studs of trolley hangers. The ground connection for lighting wires taken off the trolley circuit must be made to the track circuit.

7. All trolley and positive feed wires shall be placed on the opposite side of the track from refuge holes or necks of rooms.

8. No trolley wire shall be extended into or maintained in any room while it being used as a working place; no trolley or feed wire shall be extended into any entry beyond the outside corner of the last break-through. Trolley wires must be kept back of the last breakthrough and at least 50 feet back of the first room where pillars are being drawn.

9. Trolley wires shall be hung and kept not less than 5½ feet above the rail and shall be securely fastened and not permitted to sag.

10. All trolley wires shall be carried at least 6 inches outside of and parallel with the track rail.

11. Electric haulage by locomotives operated from a trolley wire is not permissible in any gassy portions of mines, except upon the intake air, fresh from the outside.

12. Trolley wires or other exposed electrical wires shall not carry a pressure above 275 volts.

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13. In new installations the wire shall be shielded unless it is at least 7 feet above the top of the rail.

14. Underground trolley lines should be sectionalized by placing at every thousand feet in the line a switch which can entirely disconnect the line from the power supply.

15. Overhead lines above ground: Overhead transmission lines between the generating station or substation and the mine entrance shall be supported upon insulators, which shall be adequate in quality, size, and design for the voltage transmitted. Where such a line is more than 500 feet long, lightning arresters shall be installed in connection therewith at the entrance to the mine. Such line except in the case of trolley wires, shall be maintained not less than 14 feet above the ground at the lowest point, except at the point of entrance to the mine.

Mining Laws Reviewed in Survey of Regulations Pertaining to Trolley Wires

Mining Law of the State of Alabama		1928
Mining Code of the State of Arizona		1921
Electrical Safety Orders of California		1925
Mine Safety Orders of California (Mineral Mines Other than Coal)	Effective January 1,	1921
Coal Mining Laws of Colorado		1925
Bulletin No. 9, Mine Safety Standards (Metal Mines)	June 1,	1920
Mining Laws of the State of Idaho	Effective May 8,	1919
Laws and Regulations Governing the Operation of Metal Mines in Illinois	Effective January 1,	1922
Mining Laws of the State of Illinois		1927
Mining Laws of Indiana	In force,	1927
Mining Law of Iowa	Code of	1924
Kansas Mining Laws	May,	1918
Mining Laws of the State of Kentucky		1920
Mining Laws of the State of Maryland		1923
Mining Laws of Michigan		1913
Labor Laws of New Jersey		1921
Rules Relating to Mines (Mineral - Other than Coal- Mines of New York)		1918
Mining Laws of Ohio		1927
Bituminous Mining Laws of Pennsylvania		1921
Coal Mining Laws of Texas		1916
General Coal Mine Safety Orders (Utah)	Effective September,	1920
	Amended April 8,	1924
General Safety Orders Covering Underground Metal Mining Operations of Utah	Effective August 15,	1919
Mining Laws of Virginia	Effective June 16,	1924
Coal Mining Laws of Washington, as amended	1919 and	1927
Mining Laws of the State of West Virginia	Effective July 21,	1925
Coal Mining Laws of the State of Wyoming		1919

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